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# A simulation of line-store standards conversion without interpolation

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THE BRITISH BROADCASTING CORPORATION
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RESEARCH DEPARTMENT

# A SIMULATION OF LINE-STORE STANDARDS CONVERSION WITHOUT INTERPOLATION

Technological Report No. T-121
(1964/5)

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## SUMMARY

This report describes experiments carried out in order to study some of the fundamental effects associated with the process of line-store standards conversion. These effects were studied by employing a simulation technique which is explained in detail. The design of the necessary apparatus is described, and its performance discussed.

## 1. INTRODUCTION

So far, all television standards converters have been of the image-transfer type in which the incoming television picture is displayed on the screen of a suitable cathode-ray tube and is 'read off' by a camera operating according to the desired output standard. Such converters are capable of a very good performance, but are usually rather critical to adjust and require careful setting-up by skilled engineers each time they are used.

This has led to proposals[1,2] for new forms of standards converters in which no intermediate optical images are used. These line-store converters are suitable for application where the field periods of the input and output signals are of identical duration and are co-phased. They operate by splitting each line of the incoming video waveform into a large number of elementary samples, feeding these one by one into some form of store, and reading them out again according to the output line standard. They also utilize some form of interpolation in order to remove some of the unpleasant effects of the time redistribution process which takes place in the stores.

The development of such a converter is clearly a costly and time-consuming process, and before such a programme of work was undertaken it was thought desirable to try to assess its probable performance by means of simulation. This simulation was solely concerned with the time redistribution process, and no attempt was made to introduce any form of interpolation at this stage in the work.

## 2. METHOD USED FOR SIMULATION

### 2.1. General

Conventional methods of generating or displaying a television picture involve a scanning process. A scene to be televised is scanned in horizontal lines (line scan) so arranged that each successive line is vertically displaced from its predecessor (field scan). Standards conversion from one television standard to another having a different number of lines per field, but an identical and co-phased field period, only involves altering the number of horizontal scans carried out in each field. Since each output field period is equal to an input field period this necessarily means that the duration of each line is changed and, as a result of altering the number of lines per field, the vertical spacing of the lines is also changed.

A simple example of a conversion from one sequential scanning standard to another of half the number of lines per field illustrates these two changes. Fig. 1 shows the scanning of a scene by two such television standards; the scanning lines of the higher* standard are shown full, and those of the lower standard are shown dashed. It is easily seen that the lines of the lower standard have twice the vertical spacing of those of the higher standard. Also, if the two scanning standards have identical field periods, it is clear that the duration of each line of the lower standard must be twice that of each line of the higher standard. For all broadcast television standards, the velocity of the scanning spot, along each line, is very high compared to the maximum velocity of movement which can be appreciated by the viewer; thus the process of doubling the duration of a scanning line, without disturbing the spatial distribution of information along the line, will not produce any noticeable subjective effects, and this fact suggests a means whereby simulation of conversion from the higher standard to the lower standard may be effected.

Referring to Fig. 1, real conversion would consist of discarding lines 2, 4, 6 ..... of the higher standard and doubling the durations of lines 1, 3, 5 ..... in order to occupy the total field time available. This means that, in the displayed output picture, the brightness information on line 1' of the new standard would be derived from that on line 1 of the old standard, that on line 2' from line 3, that on line 3' from line 5 and so on. If, therefore, to a picture conforming to the input standard a suitable waveform (referred to later as the 'perturbing' waveform) were added to that normally used to provide the field scan, so that the

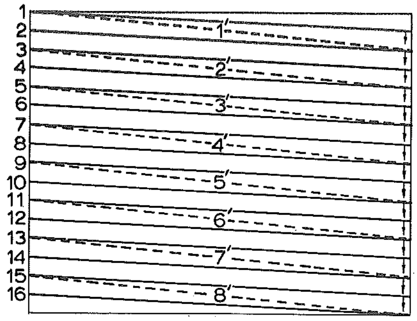

*Fig. 1 - Raster diagram illustrating simulation of conversion*

| | |
|---|---|
| 1,2,3 ..... | Line numbers (higher standard) |
| 1'2'3'..... | Line numbers (lower standard) |
| ——— | Higher-standard raster |
| ----- | Lower-standard raster |

---

* The terms higher and lower refer to the relative number of lines in the two standards considered.

right-hand end of each line scan were displaced downward by a distance equal to the spacing between adjacent lines of the input standard (as shown in Fig. 1 by the small arrows), the raster shown in Fig. 1 in full lines would be modified so that every other input line coincided with one of the lines of the output raster (shown dashed). Further, if each input line which does not coincide with an output line were blacked out, a picture would be produced which would be identical in appearance with one produced by a real standards conversion. This technique of adding a perturbing waveform to a field-scan waveform can thus form the basis for simulating standards conversions.

An alternative method for simulating conversion between these two very simply related standards is to apply the perturbing waveform to the field-scan of the picture-generating source. In this case, the picture source is scanned in accordance with the desired output line standard, in this case the lower, and the right-hand end of each picture source scanning line is displaced upward by the distance between two successive lines of the higher standard. This results, as before, in each line of the lower standard being coincident with a line of the higher standard. Thus the video signal generated at the lower standard contains exactly the same brightness information as if it had been obtained by discarding every other line of the higher standard, and the appearance of this picture, when viewed on a monitor, is exactly the same as that obtained by operating both picture source and display in accordance with the higher standard and perturbing the display-monitor scans. Thus a downwards conversion may be simulated by perturbing either the picture source, or the display monitor.

### 2.2. Choice of standards between which simulation of conversion is convenient

Fig. 1 illustrates the simulation of conversion between two television standards in which there is a very simple relationship between the number of lines employed, i.e., 2 : 1, and it has been shown that, at least for those lines which are not to be blanked out, the scanning spot must be increasingly displaced from its normal course as it moves from the left-hand to the right-hand side of the picture. This implies that the perturbing waveform to be added to a normal field-scan waveform has discontinuities where the required displacement of the spot from its normal position changes abruptly from a maximum value to zero. The number of such discontinuities in each field is equal to the difference between the number of lines-per-field used by the input and output standards, since the perturbation must be zero when the scanning lines of the two standards would coincide. If, therefore, dividing either number of lines-per-field by the number of discontinuities per field does not yield a whole number, some of these discontinuities will occur during active line periods. To simulate conversion in these circumstances would call for a very rapid response from the deflexion system, as the position of a scanning beam would have to be changed within the time of one picture element. The development of such a deflexion system would be very time-consuming. We therefore turn to an alternative approach.

If, in the case of both input and output standards, dividing the number of lines-per-field by the difference between the numbers of input and output lines-per-field yields a whole number, the discontinuities in the field scan waveform always occur at the same time relative to either set of line-synchronizing pulses. These discontinuities can, therefore, be arranged to occur during line-blanking periods, thus making several microseconds available for each repositioning of the spot. A field-deflexion system with such a speed of response is not difficult to make.

A further advantage of choosing standards such that, in each case, the number of lines-per-field is an integral multiple of the difference in the number of lines-per-field is that all the necessary scan perturbations can be derived, from line-frequency pulses of either standard by means of simple counters.

The foregoing argument implies that the simulation of conversion from 625 to 405 lines is not possible because the number of lines-per-field of either of these standards is not divisible by the difference in the numbers of lines-per-field. It is necessary therefore, to seek two suitable numbers of lines-per-field, close to 312 1/2 and 202 1/2, which fulfil the required conditions. Two such numbers are 312 and 208, (in the ratio of 3 : 2), which correspond to standards of 624 and 416 lines per picture respectively. These are, however, sequential scanning standards and in order to carry out a more realistic conversion (all television standards in broadcasting employ simple interlace) it is necessary to add one line to each standard, thus converting from 625 to 417. Any small errors resulting from the addition of the extra line may be corrected by adding, to the scan perturbation, a small magnitude picture-frequency sawtooth, and by rephasing the scan perturbation at the commencement of each picture. This technique is explained in more detail in Section 2.3.

## 2.3. Derivation of the required scan perturbations

### 2.3.1. General

It has been shown that the simulation of conversion requires the addition of certain waveforms to the field scan of either a picture source or a display device. In order to describe, in detail, the exact shape and amplitude of these waveforms, it is convenient to consider two specific conversions, the first from the higher standard to the lower and the second from the lower standard to the higher, where, in each case, the relation between the line standards is (3n + 1) : (2n + 1) and n is a whole number.

Two such convenient numbers, which are small enough to enable diagrams of complete rasters to be easily drawn, are 19 and 13.

### 2.3.2. Simulation of downward conversion - field scan of picture source perturbed

Fig. 2 consists of diagrams illustrating a simulated conversion from 19 to 13 lines.

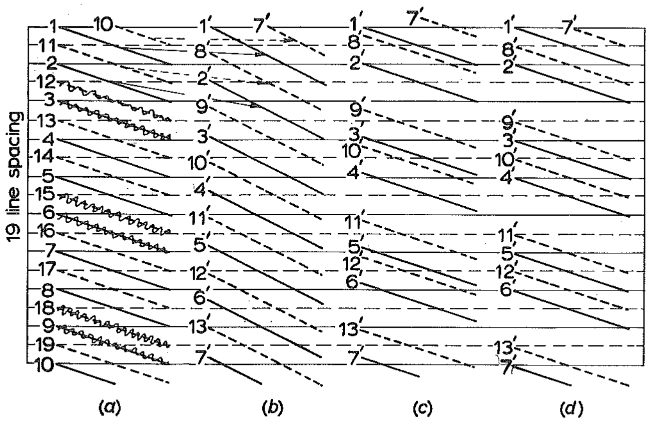

*Fig. 2 - Raster diagrams illustrating 19 → 13 line conversion*

(a) Original 19-line raster
(b) Required 13-line raster
(c) Raster (b) partly perturbed
(d) Raster (b) fully perturbed
1,2,3, ..... Line numbers (19-line raster)
1'2'3' ..... Line numbers (13-line raster)
——— Lines of odd fields
— — — Lines of even fields

Fig. 2(a) shows a 19-line picture raster, the first field being shown in full lines, and the second (interlaced) field in broken lines. Those lines that are to be discarded in the simulation have been lightly crossed out.

Fig. 2(b) shows a 13-line raster arranged to scan exactly the same picture area as the 19-line raster in Fig. 2(a). The arrows joining the two rasters indicate those lines of the 19-line picture from which the lines of the 13-line picture are derived. From Section 2.2. it will be seen that it is necessary to displace each line of the 13-line raster so as to occupy the position of the corresponding line in the 19-line raster. If the ratio between the numbers of lines in the two standards were exactly 3 : 2, this could be achieved simply, as explained previously, by adding to the field-scan a sawtooth, at one-half line frequency, of appropriate magnitude (in this case 2/19 of the picture height). As the ratio is not exactly 3 : 2, however, the addition of this sawtooth alone leads to a linearly increasing positional error which reaches 1/19th of the picture height at the end of the last line of the 13-line raster. This effect is shown in Fig. 2(c). The addition of a suitable picture-frequency waveform of amplitude 1/19th of the picture height corrects this error; the resultant scan is shown in Fig. 2(d).

By this process the 13-line raster has been distorted so that each line scans the scene as though it were the corresponding line of an undistorted 19-line raster. The displayed picture, resulting from analysis of the scene in this manner, would then appear exactly as if it had been obtained by using a line-store standards converter, without interpolation, in order to convert from a 19-line to a 13-line system.

It will be noticed that if the 'line discarding' process were continued into the next picture by discarding every third line, the picture lines to be discarded would be numbers 2, 5, 8, etc., and not 3, 6, 9 - as in the first picture. This is obviously wrong, since in a real conversion the true scanning patterns are fixed with respect to each other, and stroboscopic effects such as this cannot occur. This effect can be corrected by rephasing the one-half line-frequency sawtooth at the beginning of each picture interval, thus ensuring that this waveform starts in the same phase at the beginning of each picture.

The foregoing discussion applies equally to a simulated conversion from 625 lines to 417 lines, as these numbers also have the same (3n + 1) : (2n + 1) relationship. These are the standards which have, in fact, been used in subjective tests as, for practical purposes, the results obtained are substantially identical to those that would be obtained if the simulated conversion were from 625 to 405 lines.

### 2.3.3. Simulation of upward conversion - field scan of picture source perturbed

This is illustrated in Fig. 3. Fig. 3(a) shows the 13-line raster and Fig. 3(b) the 19-line raster. In this simulation a 19-line raster is used for scanning the display device and the 19-line raster at the source is perturbed so that it scans the scene only where lines of a 13-line raster would fall. Thus the video information obtained during each line is the same as if it were derived from the corresponding line of Fig. 3(a).

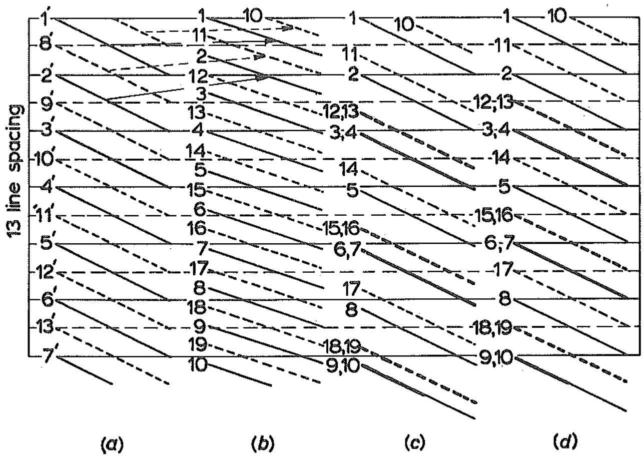

*Fig. 3 - Raster diagrams illustrating 13 → 19 line conversion*

(a) Original 13-line raster
(b) Required 19-line raster
(c) Raster (b) partly perturbed
(d) Raster (b) fully perturbed
1, 2, 3, ..... Line numbers (19-line raster)
1'2'3' ..... Line numbers (13-line raster)
———— Lines of odd fields (overlapping lines
- - - - Lines of even fields are shown thicker)

Figs. 3(c) and 3(d) show this being achieved in two stages as before. Fig. 3(c) shows the addition, to the picture-source field scan, of a one-third line-frequency sawtooth having a magnitude 3/19th of picture height. This, as before, leads to an increasing error in line position which may be corrected by adding a picture-frequency sawtooth having a magnitude 1/19th of picture height. The extra half line at the bottom of Fig. 3(d) is due to simulating a half line by shifting a whole line; this is an inevitable consequence of this method of simulation. As stated in Section 2.3.2. it is necessary to rephase the one-third line-frequency sawtooth at the beginning of each picture interval.

### 2.3.4. Simulation of downward conversion - field scan of display perturbed

It will be seen from Fig. 3 that the 19-line raster of Fig. 3(b) may be perturbed in order to provide the 13-line raster of Fig. 3(d). Therefore, if the 19-line raster of a display is perturbed in the same way, a 13-line raster may be produced on the display screen. However, some of the lines will scan the same path twice and they will appear brighter than the rest. Further, each 'double' line contains information from two of the 19 scanning lines. It is necessary, therefore, to provide a blanking waveform to blank out one line of each superimposed pair. This results in a 13-line picture, each line of which has been derived from the appropriate line of the 19-line picture.

## 2.4. Required waveforms

From Section 2.3., the waveforms required in order to perform all the simulations mentioned are as follows:

(i) A field-frequency sawtooth providing normal scan.

(ii) A one-half or one-third line-frequency sawtooth which must be rephased at the beginning of each picture.

(iii) A picture-frequency sawtooth.

(iv) A one-third line-frequency square wave with 1 : 2 mark-space ratio, for display blanking.

Arrangements must be made for combining two or more of the waveforms (i), (ii) and (iii) in the appropriate proportions and with the correct polarities, and for transforming the resultant waveform into corresponding current variations in a field-scanning coil.

## 3. APPARATUS

### 3.1. General

Simulation equipment has been developed which provides two independent outputs of field scan mixed with independently adjustable amounts of one-half or one-third line-frequency and picture-frequency perturbing waveforms. This arrangement permits the outputs to be fed to both a film scanner and a slide scanner simultaneously. In such circumstances, the facility of providing different amounts of perturbing waveform in each output is essential since, in a continuous-motion film scanner, half the vertical scan is provided by the motion of the film itself and therefore the ratio of the magnitudes of the normal field scan (waveform (i)) to the perturbing waveforms (ii) and (iii) is half that required by a slide scanner.

The functions outlined above are performed in three units; these consist of a waveform generator providing two independent, composite, scanning-and-perturbing waveforms together with two output units each mounted close to an associated deflexion coil. The waveform generator and output unit designs will be described separately. A Research Department 21 inch (53 cm) monitor was modified to accept blanking pulses (waveform (iv)) when necessary.

### 3.2. The output unit

This is a power amplifier capable of providing the required complex field-scanning current for the field-deflexion coil of a scanner or monitor. A coil has an inductance of about 300 $\mu$H, a resistance of 0·5Ω and requires a scanning current of about 3 A peak-to-peak. Because of the complex nature of the scanning waveform it is necessary that the frequency response of the scan circuit extends from well below 25 c/s to about 100 kc/s. A suitable method of driving the coil employs directly coupled transistors; it is, however, necessary to devise a circuit in which no 'standing' direct current flows through the coil as this could result in an unwanted shift of the raster. An arrangement which fulfils these requirements is the so-called single-ended push-pull circuit,[3] in which the load is placed between the junction of two series-connected transistors and the centre tap of the power supply.

The circuit of the coil drive unit is shown in Fig. 4. VT4 and VT5 are the output push-pull pair which are driven by a phase splitter VT3. VT1 and VT2 drive the phase splitter, feedback being applied from the output to the emitter of VT1 in order to linearize the amplitude characteristic; the bias to VT1 is used as a vertical-shift control. VT6 is used for monitoring the scan current; it amplifies the voltage appearing across the 0·3Ω resistor, and is deliberately arranged to limit at the top and bottom of the normal scan waveform. VT6 thus provides a 'magnified' version of a part of the field scan and enables the degree of perturbation to be accurately measured.

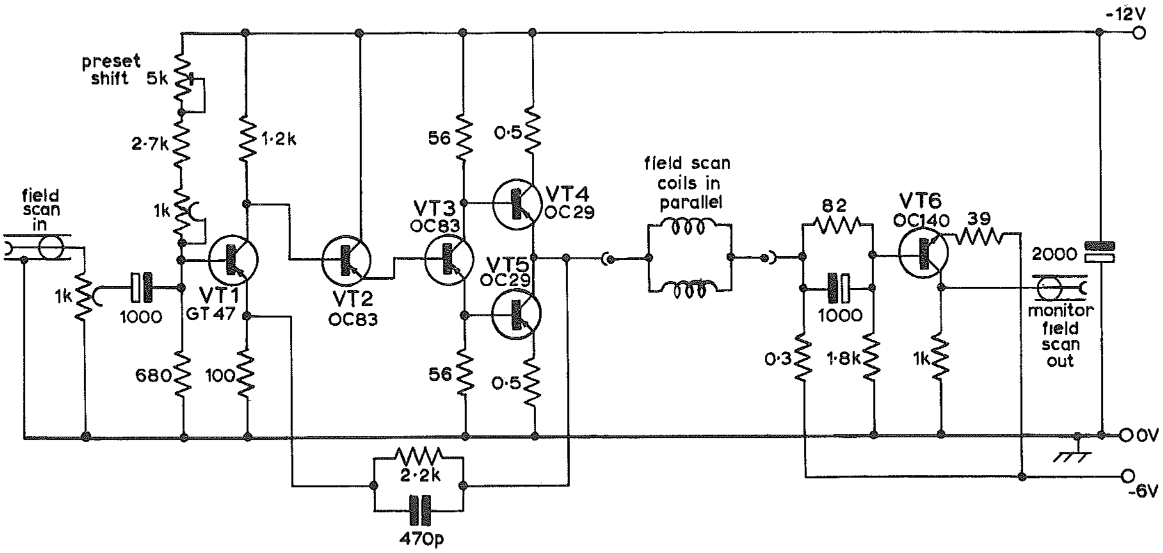

*Fig. 4 - Field scan output unit*

The unit provides field scan of adequate linearity for the purpose required. The d.c. stability is not of a very high order and the circuit is rather susceptible to variations in room temperature but, nevertheless, it has proved adequate for experimental purposes. The transient response of the unit is sufficiently good for the flyback time of the perturbing sawtooth to be about 10 $\mu$s.

### 3.3. Field sawtooth and perturbing-waveform generator

This unit, which is also completely transistorized, accepts line and field trigger pulses, and contains the dividers and the sawtooth and square-wave generators. A block diagram is given in Fig. 5, and the various sections will be described separately. The full circuit is shown in Fig. 6.

### 3.3.1. Field sawtooth generator

Field trigger pulses are used to synchronize a blocking oscillator; this ensures that if the supply of drive pulses fails, the main component of field scan is still operative. The output from the oscillator drives a 'bootstrap' sawtooth generator, the output of which feeds the two mixing and output circuits mentioned in Section 3.1.

### 3.3.2. One-half or one-third line-frequency sawtooth generator

Line frequency pulses are fed to a divider that can be switched to divide by either 2 or 3 as required, thus providing one-half line-frequency pulses for downward conversion simulation with source perturbation, and one-third line-frequency pulses for other forms of simulation. The output of the divider triggers a sawtooth generator that includes a suitable shaping network compensating for the inductance of the scanning coils. The shaped sawtooth waveform then passes to a phase-splitter so as to enable the polarity of the added perturbing waveform to be reversed when necessary. The sawtooth component is then added to the other waveforms in the mixer stages.

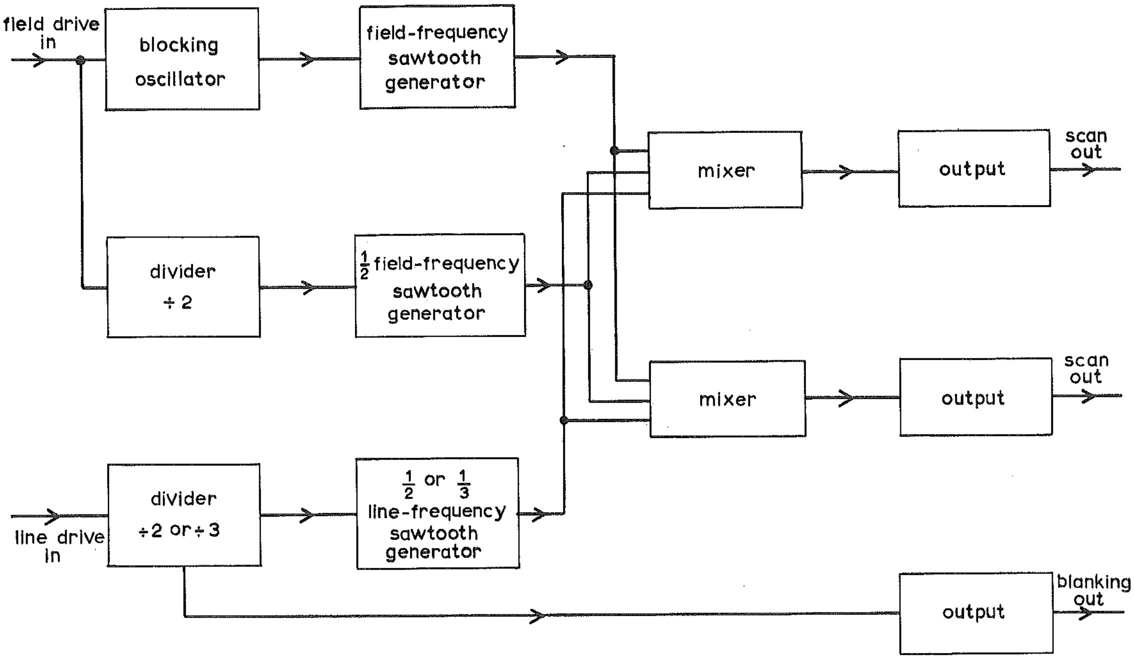

*Fig. 5 - Block diagram of perturbation generator*

### 3.3.3. Picture-frequency sawtooth generator

The frequency of field trigger pulses is divided by two in a simple binary divider; the output can be taken from either collector in order to allow the picture-frequency sawtooth to commence on either the odd or even field. These picture-frequency pulses trigger another bootstrap sawtooth generator, the output of which is mixed with the other waveforms.

### 3.3.4. Blanking waveform generator

The blanking waveform is obtained by a tapping at the appropriate point in the divider described in Section 3.3.2. Since a blanking waveform is used solely for blanking the display in simulating downward conversion, the blanking waveform is only required when the divider is in the 'divide-by-three' condition.

## 4. OPERATION

In order to adjust the magnitudes of the perturbing waveform to the correct values, two different methods are adopted. The first, which is applicable to a downward conversion when the picture source is perturbed, relies upon a suitable graticule attached to an oscilloscope. A diagram of such a graticule is shown in Fig. 7. By this means the current waveform may be observed at the monitoring point provided, and adjustments may be made until the waveform coincides with the graticule engraving.

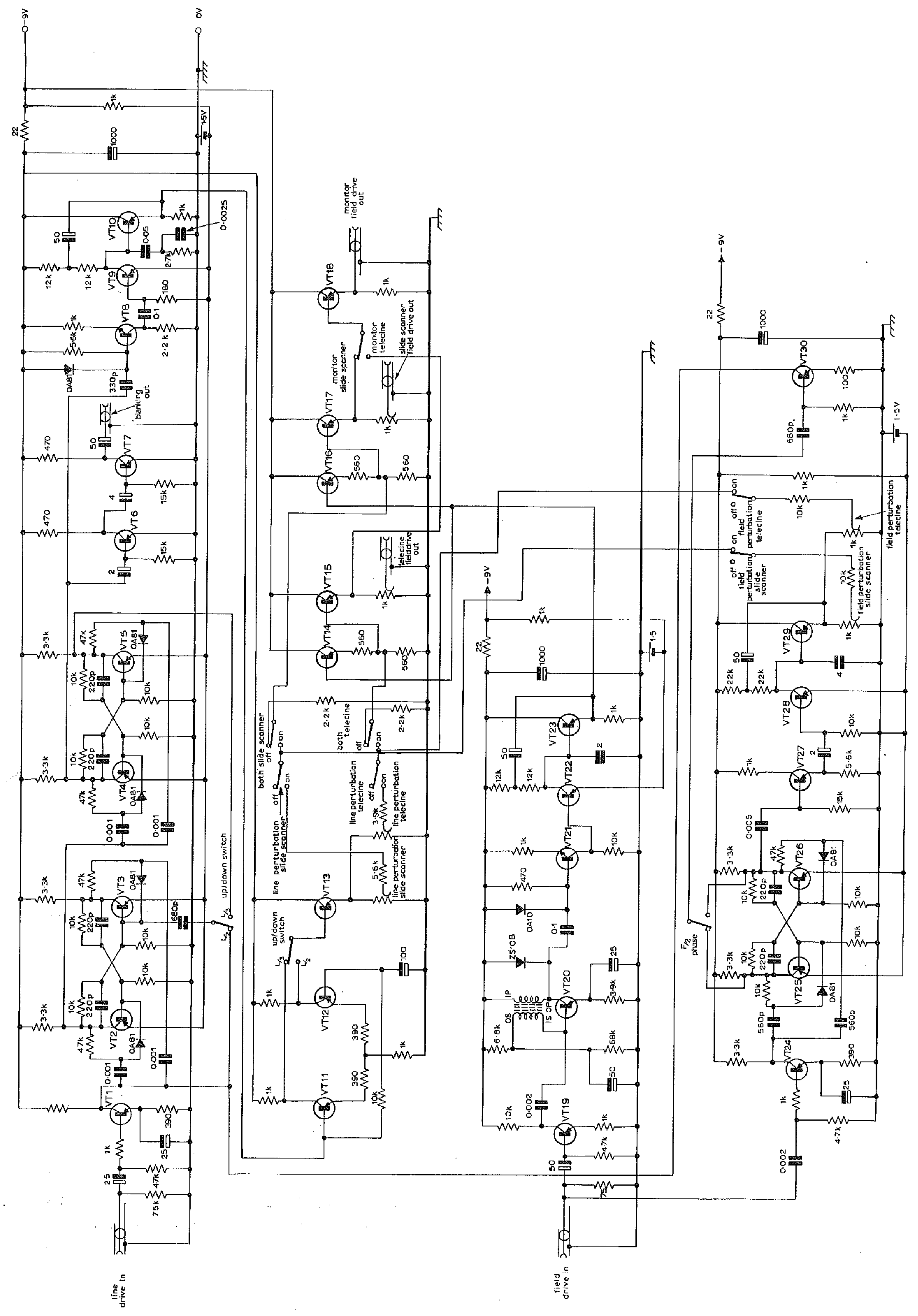

*Fig. 6 - Perturbation and field scan generator*

For upward conversion, or for downward conversion where the display is perturbed, a second, much easier and more accurate, method is available. Reference to Fig. 3(c) shows that, when the magnitude of the one-third line-frequency sawtooth is correct, certain lines of the picture lie immediately on top of each other. This condition is very easily observable on a display tube and enables the magnitude of the one-third line-frequency sawtooth to be set accurately. All that remains is to adjust the magnitude of the picture-frequency sawtooth so that the scanning lines are equally spaced - another very easily observable condition.

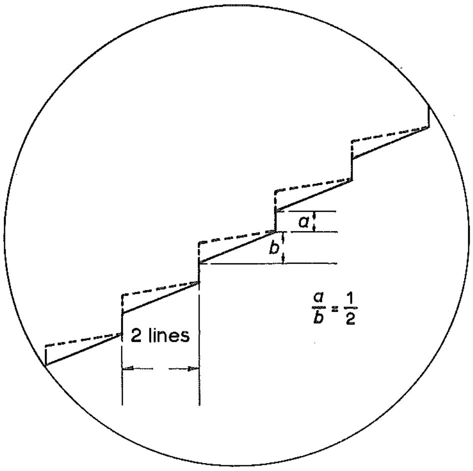

*Fig. 7 - Graticule for adjustment of perturbation amplitude*

——— For slide scanner
– – – For film scanner

## 5. RESULTS

The equipment gives a performance adequate for the purpose for which it was designed. Figs. 8 and 9 show photographs of Test Card 'C' in which downward and upward conversions respectively have been simulated. From the pictures it will be seen that in each case there is a 'sawtooth' effect on diagonal picture features which results from the omission of lines of picture information (in the case of downward conversion) and the insertion of incorrectly positioned information (in the case of upwards conversion). Inaccuracies can be seen around the periphery of the picture; these are mainly due to defects in the coil-drive unit. The performance over the greater part of the picture area is, however, satisfactory.

## 6. CONCLUSIONS

Observations of pictures produced by simulation have made it clear that a converter working purely on the 'line discarding and time stretching' principle does not produce pictures of adequate quality, and that some form of interpolation[4] is necessary.

## 7. REFERENCES

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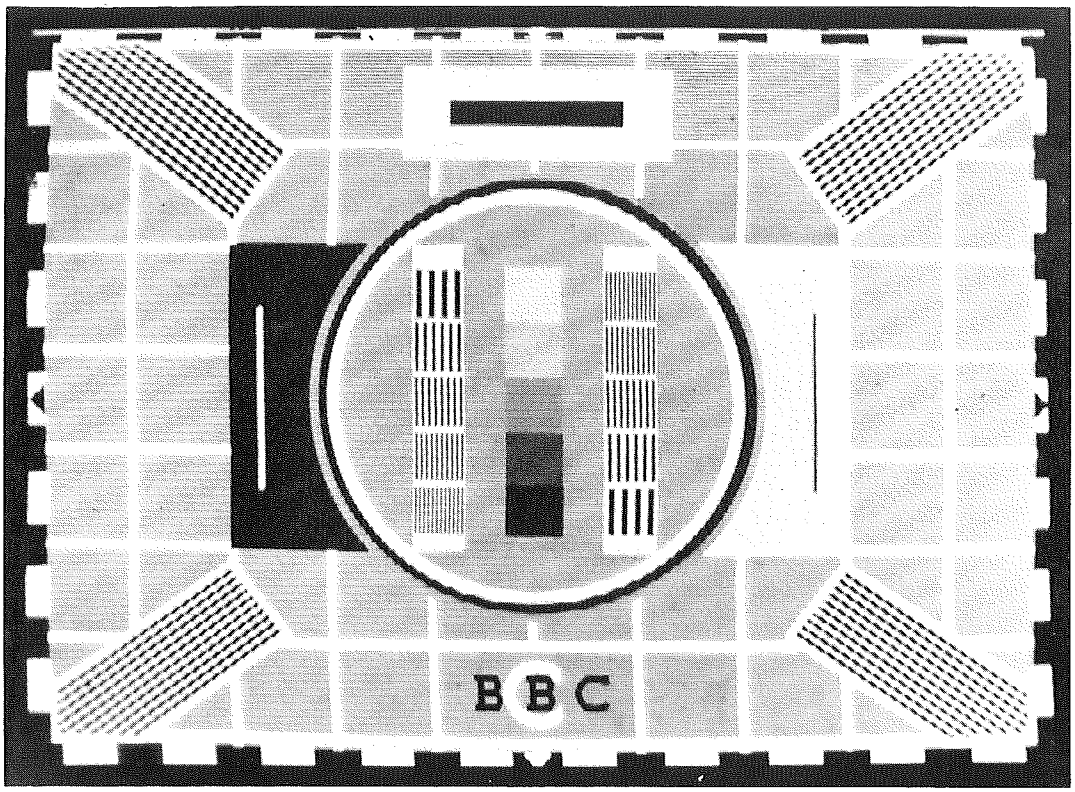

*Fig. 8 - Downward conversion 625 → 417*

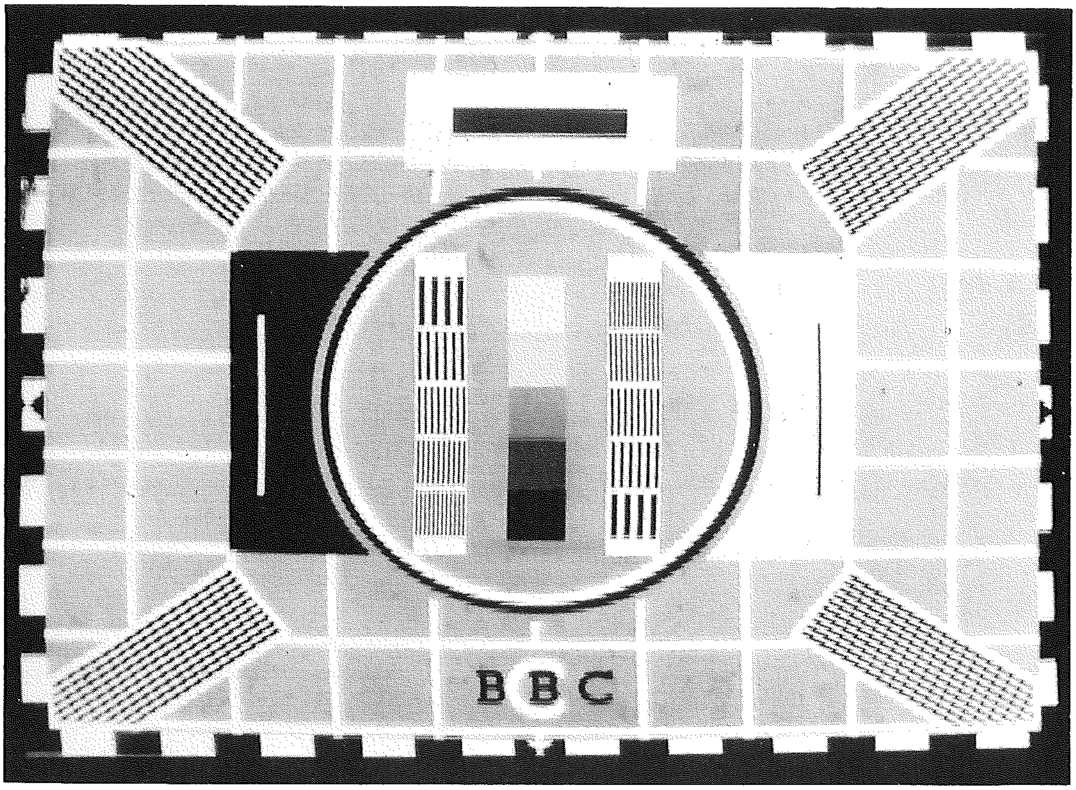

*Fig. 9 - Upward conversion 417 → 625*

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